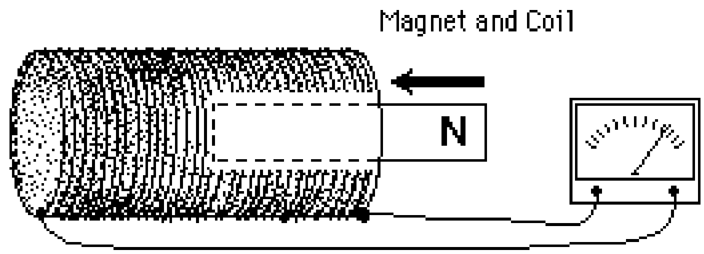
# <u>Induced EMF</u>

It was determined from the last section that a current produces a magnetic field. This phenomenon also works in reverse: magnetism can produce current electricity in a wire, so long as the magnetic field is moving past the wire, or the wire is moving through the magnetic field.

In fact, it was first determined in the 1800's by Michael Faraday that, athough a stationary magnetic field **B** had no effect on a conducting wire, a moving or *changing* magnetic field can produce an **induced** electric current in the wire.

Consider the diagram below:




- as **B** changes (i.e. as the magnet is moved in through the solenoid), a current flows in the coils as if there was a source of EMF in the current.
- if the magnet sits stationary in the solenoid (so that **B** is <u>not</u> changing), <u>no</u> current flows in the coils.

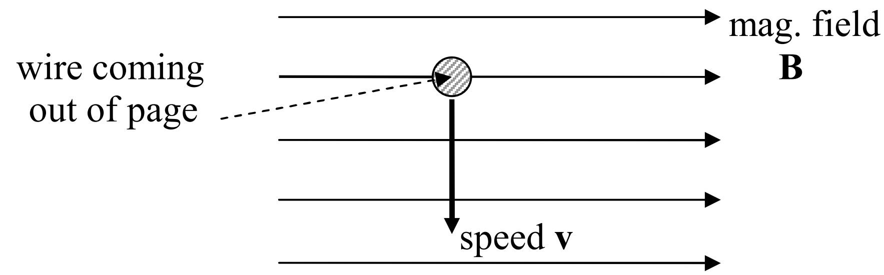
Therefore, it can be stated that an *induced* EMF is created by a changing (moving) magnetic field; this process is known as *electromagnetic induction*. Note that the induction effect can be created in a wire by moving an external magnetic field, <u>or</u> by moving the wire in a stationary **B** field.

**Example #1: Two solenoids are placed side-by-side. The first is connected to a power supply and a switch; the second is connected in a <u>separate</u> circuit to a galvanometer, which detects current movement. Can the first solenoid induce a current in the second one? Explain your answer.**

**(see Induction Ex 1 for answer)**

Inducing EMF in a Straight Piece of Wire

Examine the diagram below:




If a wire of length $l$ moves through a magnetic field **B** at right angles to the field lines, an EMF will develop between the ends of the conductor, resulting in a current flow in the wire.

Use the **RHR** to determine the direction that a positive charge will move within the moving wire above; this will be the direction of *conventional* current in the wire. With your palm flat, fingers together:

- point your thumb in the direction that the wire is moving;
- point your fingers in the direction of the magnetic feld;
- your palm will face the direction that positive charged are "pushed" in the wire.

In the diagram above, the positive charges in the wire must move *out-of-page*. If you use the left-hand-rule, you can prove that negative charges in the wire move *into-the-page*. What does all this really mean? It means that charges are *separated* to either end in the moving wire, creating a potential difference and an induced EMF.

The *magnitude* of the induced EMF ($\varepsilon$) can also be determined:
Start with the equation for magnetic force acting on a charge **q** (in the wire),

$$\mathbf{F = qvB}$$

- work has been done to move **q** the full length $l$ of the wire; that is,

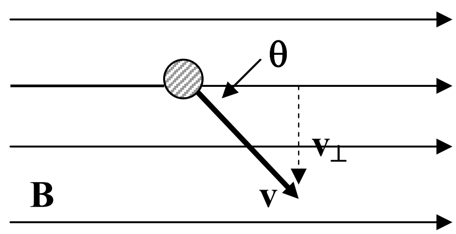
$\mathbf{W = Fd = qvB}l$ → but **W** = change in energy **ΔE**

and $\mathbf{\Delta E = qV}$ → where **V** is the EMF $\varepsilon$ in the wire

- so $\mathbf{q}\varepsilon = \mathbf{qvB}l$ which becomes $\boxed{\varepsilon = \mathbf{vB}l}$

Note that for the purposes of this course, **v**, **B** and ***l*** all must be perpendicular to each other in order for an EMF to be induced. Think of the wire like a blade of a lawnmower, and the field lines **B** as blades of grass. To induce an EMF, the lawnmower blade (the wire) must be moved so it "cuts" the grass blades (the field lines **B**). If the wire is moved *parallel* to **B**, no EMF is induced.

Aside: In college physics, you will learn that if the moving wire is moved at some angle *other than* 90° to the field **B**:




→ consider only the ⊥ component of **v** relative to **B**, so that

$$\varepsilon = vBl \sin\theta$$

**Example #2: A copper bar 30 cm long is perpendicular to a field of strength 0.80 T and moves at right angles to the field with a speed of 50 cm/s. Determine the EMF induced in the bar.**

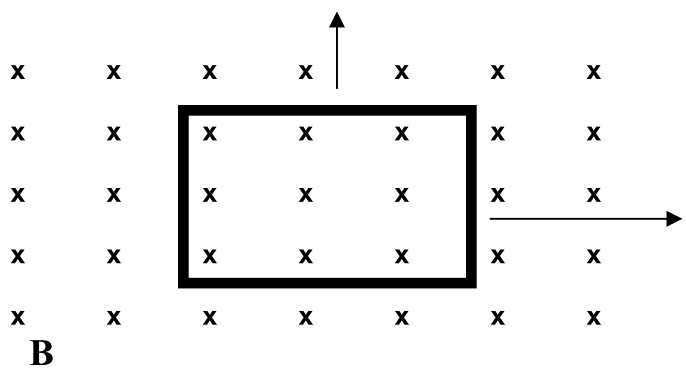
**(see Induction Ex 2 for answer)**

**Example #3: A train is moving directly south at uniform speed. If, at this location, the vertical component of the Earth's magnetic field is $5.4 \times 10^{-5}$ T, and the EMF induced in a 1.2 m-long car axle is $6.5 \times 10^{-5}$ V, how fast was the train going?**

**(see Induction Ex 3 for answer)**

**Example #4: A rectangular loop of wire is placed in a magnetic field as shown. Explain what will happen when the loop is moved:**

a) **to the right;**
b) **up toward the top of the page.**




**(see Induction Ex 4 for answer)**